NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences – 2009
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A.29 HyspIRI Preparatory Activities Using Existing Imagery

The National Aeronautics and Space Administration (NASA) Earth Science Division within the Science Mission Directorate solicited proposals for investigations for HyspIRI preparatory activities using existing satellite and airborne imagery.

In response to the National Research Council (NRC) report *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, the solicitation requested research investigations supporting the development of concepts for a Hyperspectral Infrared Imager (HyspIRI) mission. In doing so, it sought to engage potential research communities in preparation for data from a future HyspIRI mission. The solicitation called for the assembly of HyspIRI-like data sets from existing high-altitude airborne and/or satellite platforms carrying imaging spectrometers (focused on the visible to shortwave infrared region of the electromagnetic spectrum) and multispectral thermal infrared instruments.

NASA received a total of 28 proposals and has selected 6 for funding at this time. The total funding to be provided for these investigations is approximately $600,000 over the next year. The investigations selected are listed below.

Michael Abrams/Jet Propulsion Laboratory
HyspIRI Preparatory Data Sets for Volcanology

HyspIRI is a Tier 2 mission recommended to NASA by the National Research Council's Decadal Survey report. One of the main goals of the HyspIRI mission is to provide global observations of surface attributes at local and landscape spatial scales (10’s of meters to hundreds of kilometers) to map volcanic gases and surface temperatures, which are identified as indicators of impending volcanic hazards; as well as plume ejecta which pose risks to aircraft and people and property downwind. We will create precursor HyspIRI data sets for volcanological analyses, using existing data over Mt. Etna, Italy. We have identified 12 EO-1 Hyperion data acquisitions, 12 near-coincident ASTER data acquisitions, and a MIVIS aircraft data acquisition, covering six eruptive periods between 2001 and 2007. These three data sets provide us with 30 m hyperspectral VSWIR data and 90 m multispectral TIR data (satellite) and 10 m multispectral TIR data (aircraft). They will allow us to examine temporal sequences of several Etnaean eruptions. We will address the following critical questions, directly related to understanding eruption hazards: 1) What do changes in SO_2 emissions tell us about a volcano's activity? How well do these measurements compare with ground-based COSPEC measurements? 2) How do we use measurements of lava flow temperature and volume to predict advances of the flow front? 3) What do changes in lava lake temperatures and energy emissions tell us about possible eruptive behavior?

Mapping SO_2 emissions will be done using REALMUTO Software applied to our precursor HyspIRI data sets. We will calculate, through data analysis and models, the column abundance of SO_2 all along Etna's plumes. Results will be compared with coincident COSPEC ground measurements at Etna obtained daily by Istituto Nazionale del Geofisica e Vulcanologia in Catania, Sicily. Examining the time history of SO_2, compared with eruption history, will provide us some indication of the correlation between the two.

Data from the VSWIR and TIR will allow us to determine radiant temperatures over a wide range: edges of lava flows at 100C, to magmatic lava at 1100C. This improved characterization of flows is a crucial input into flow models for predicting run-out lengths. Similarly, improved accuracy for determining temperatures of lava lakes will provide better insight into the internal plumbing of Etna, and the state of magma ascent from depths.

In the area of sensor modeling we will fix the Lmax values for the 4 micron channel and examine the recommendation for a low gain 8-14 micron channel. We will simulate, in general, the response of HyspIRI (both the VSWIR and TIR) to active lavas using a combination of high resolution FLIR images, Hyperion spectra, Landsat images to simulate (using a stochastic approach) the surface leaving radiance from real lava flow fields. Convolving this with spectral response curves and PSFs for HyspIRI will allow us to analyze how lava flows will be sensed by HyspIRI.

We have assembled an extraordinary team of experienced and expert remote sensing volcanologists: three were members of the EO-1 Science Team; two are 10+ year members of the ASTER Science Team, three have years experience working with MIVIS data. Our team pioneered the extraction of SO_2 concentrations from TIR data, and has been instrumental in development of analyses of volcanological thermal phenomena using remote sensing data. All are respected contributors to the peer-reviewed scientific literature.

Precursor HyspIRI data sets will be shared with the scientific community through an FTP site running at JPL. We will publicize the existence of these data sets by emails to IAVCEI and IWG-everybody mail-lists. Additionally, we will present our results at the AGU Conference, and submit the results for publication.

This work is proposed to be conducted as Fundamental Research.

Petya Campbell/NASA Goddard Space Flight Center
Assessing Ecosystem Diversity and Urban Boundaries Using Surface Reflectance and Emissivity at Varying Spectral and Spatial Scales

With the increase in the population density and the ever expanding conversion of land from rural to urban, the urban heat island (UHI) effect has become a problem of critical importance. Land cover type and land surface temperature (LST) in urban and rural areas display significant differences, such as higher LST and lower moisture content, with increasing urbanization.

The combination of high spectral resolution optical and thermal infrared imagery of the proposed HyspIRI mission will provide a powerful capability for more precise land cover type discrimination and ecosystem monitoring than possible using current satellite systems, such as mapping of cover types, aquatic and terrestrial ecosystem identification, vegetation/soil nutrient and moisture content determinations and assessment of the ecosystems function and health.

In preparation for HyspIRI data use, and to contribute toward the development of the mission's concepts, this study will assemble existing data from air-borne (AVIRIS, MASTER) and space-borne (EO-1 Hyperion and ASTER) systems. The selected scenes cover both rural and urban environments. The goals are: 1) to generate HyspIRI-like data sets; 2) characterize the ecosystems biodiversity composition and functional groups and delineate urban and rural ecosystems; 3) determine the relationship between spectral and thermal properties of urban and rural ecosystems and of individual functional types within an ecosystem; and 4) assess the capabilities of spectral indicators of vegetation bio-physical properties and health, derived from HyspIRI-like data.

To evaluate the benefit of combining high spectral resolution optical and thermal into HyspIRI-like data, 60 m spatial resolution data, from two independent locations with different regional climate and ecosystem types, will be compared to data for the same locations aggregated to higher and lower spatial scales. By fusion of spectroscopy and thermal remote sensing, this study will assess the potential of HyspIRI-like data for delineating land covers and vegetation types, discriminating natural versus urban ecosystems, and assessing ecosystems diversity and health.

Fred Kruse/University of Nevada Reno
Characterization of Hydrothermal Systems Using Simulated HyspIRI Data

Active and fossil hydrothermal systems occur worldwide, and share many characteristics indicating common genetic histories. They are often associated with rhyolite-composition volcanic rocks and occur in areas of geologically recent folding and faulting. Surface manifestations of active systems include temperature anomalies, hot springs, geysers, fumaroles, mud pots/pools, silica sinters, sulfate minerals, tufa deposits, travertine, thermophilic vegetation, and vegetation concentrations, alignments and zonation. Fossil hydrothermal systems are present as extinct portions of active systems, and also preserved as epithermal mineral deposits. We propose research to develop improved understanding of the surface expression of hydrothermal systems, the relations between the active and fossil systems, and to determine how knowledge of surface characteristics can be used to help improve and sustain resource development. Existing NASA data will be used to simulate HyspIRI spatial and spectral resolution, building datasets that will allow determination of potential HyspIRI capabilities for resource characterization and monitoring. Key data include AVIRIS, MASTER, ASTER, Hyperion, TIMS, and MAS. Archival data at various spatial resolutions will be utilized to 1) Build HyspIRI-like datasets, 2) Identify, characterize, and map mineral assemblages associated with active and fossil systems, 3) Detect and map vegetation anomalies and distributions related to active systems, 4) Detect, map, and quantify surface temperature anomalies and variability associated with active systems, 5) Model the effects of spatial resolution and HyspIRI spectral coverage and resolution on mineral mapping and temperature determinations, and 6) Detect, characterize, and monitor surface changes associated with development and production of geothermal resources. HSI data will be converted to reflectance using an atmospheric model. LWIR data will be processed to separate temperature and emissivity. Modeling using day-night data and DEMs will allow quantitative temperature measurements and determination of anomalous heat flow at the surface. The VNIR/SWIR HSI reflectance data will be analyzed using spectral-feature-based methods to determine not only the most spectrally dominant mineral (as is commonly done now in HSI analysis), but also for identification and quantification of all spectrally active minerals at each pixel. New methods of presenting HSI-derived mineral assemblage information will be explored. Shape/slope analysis using the LWIR emissivity data will extend mapping capabilities to other rock-forming minerals. Combined analysis of the VNIR/SWIR/LWIR simulated HyspIRI data will provide a more complete picture of surface mineralogy. The proposed research builds on previous work by the PI and other UNR researchers to produce new, quantitative information and insights into the origins and nature of these systems, links between the two, and new information on resource sustainability. The calibrated, corrected, simulated HyspIRI datasets will be made publically available via the internet and research results will be published in the peer-reviewed literature. The proposed research supports several of the HyspIRI Science Questions identified in the NRC Decadal Survey and refined by the HyspIRI Science Study Groups. They include VQ6-Earth surface composition, TQ5a-Spectrally observable mineralogy of the Earth's surface and relation to geochemistry and surface processes, TQ5b-Nature and extent of man-made disturbance and variation over time, TQ5c-Relationship of surface temperature anomalies to deeper thermal sources, and CQ5-Surface composition and response to natural and anthropogenic drivers. The proposed research also meets one of the direct objectives of the NRC Decadal Survey to 'utilize remote sensing technology to better understand our planet and the effects of human activity on societal prosperity, health, and sustainability'.

Lin Li/Indiana University-Purdue University at Indianapolis
Remote Sensing of Global Warming-Affected Inland Water Quality: Challenge, Opportunity and Solution

Cyanobacterial blooms (CYBB) are one of the most important issues concerning environmental agencies, water authorities and public health organizations. Global warming-induced climate change has been considered to be a catalyst for global expansion of harmful CYBB, and this leads to critical considerations on the effect of rising temperature and increasing nutrient runoff on the occurrence of microbial agents, phytoplankton, and CYBB.

To demonstrate the efficiency of new generation satellite hyperspectral HyspIRI datasets in developing strategies for effectively addressing and managing CYBB as well as maintaining the ecological integrity and sustainability of inland drinking water bodies, this study proposes to build simulated HyspIRI datasets with EO-1 Hyperion images and EOS TERRA/ASTER thermal bands and apply them for mapping water temperature, nutrients (nitrite/nitrate, organic nitrogen, ortho-phosphate and organic phosphorus), chlorophyll a (Chl-a), and phycocyanin (PC) of three Central Indiana Reservoirs, correlate the spatial patterns of pigment concentrations, nutrients and temperature via regression analysis and build an early warning system for CYBB prediction through integration of remote sensing mapping with water quality modeling. We will address 1) for a given reservoir, what spectral parameters are more sensitive to Chl-a and PC concentration and what interfering parameters affect the performance of these spectral parameters, 2) for a given pigment, which mapping algorithm has good instrumental, temporal and spatial transferability, 3) what spectral parameters highly correlate to a nutrient constituent in drinking water and whether a correlation is causal; if not, what other water quality parameters are responsible for this correlation, 4) given the fact that temperature and nutrients are important factors for the occurrence of CYBB, whether high correlations can be observed among the spatial patterns of Chl-a, PC, nutrient constituents and temperature in these reservoirs, and 5) whether remote sensing mapping improves the parameterization of water quality models and thus their predictive power.

The result of this research will demonstrate whether HyspIRI data could contribute to the development of new algorithms for mapping Chl-, PC, nutrient constituent and temperature with the addition of thermal bands, the situations where HyspIRI images and corresponding algorithms can be applied and their limitations for mapping Chl-a, PC, nutrient constituents and temperature of inland drinking waters. The result will also help design spectral configuration of future sensors (i.e. HyspIRI) and provide the scientific basis for the new generation of water quality remote sensing. Integrating remote sensing with water quality modeling could be an effective operational tool for water quality mangers to forecast water quality and make science-based decisions on the breakout of CYBB and for posing health advisories or efficient algaecide treatments.

Philip Townsend/University of Wisconsin-Madison
Detection of Key Leaf Physiological Traits Using Spectroscopy and Hyperspectral Imagery

Spectroscopic approaches are effective for detecting important biochemical traits of leaves, such as nitrogen and lignin concentration. At present, we are using imaging spectroscopy to characterize key forest functional traits including leaf structure (essentially cell volume), shade tolerance (~ratio of chlorophyll content to leaf volume) and recalcitrance (lignin concentration). In a new pilot study, we have tested the capacity of green-leaf spectroscopy to measure other important physiological traits needed to estimate canopy photosynthesis and respiration following the Farquhar model. Because metabolic rates vary with foliar nitrogen and ambient temperature, our initial studies have been conducted experimentally on aspen and cottonwood trees under three temperature regimes and two N fertilization scenarios. Using interval-PLS, we have found strong relationships (R^2 > 0.68) between green leaf spectra and: (a) warm leaf respiration rate (normalized to 23C), (b) cold leaf respiration rate (13C), (c) CO_2 assimilation rate (on an area and mass basis), (d) specific leaf area, (e) leaf nitrogen, (f) maximum rate of carboxylation, V(c)max, and (g) maximum rate of electron transport, Jmax. Further, evaluation of spectral loadings indicate that the wavelengths important to prediction correspond to known sensitivities within spectral data, e.g. wavebands related to N, water, and chlorophyll content, and structural characteristics of the spongy mesophyll. We propose to test the potential for extending our spectroscopic measurements to hyperspectral imaging. Using existing AVIRIS and Hyperion imagery with our field data and the SAILH radiative transfer model, we will demonstrate the scaling of these variables to the canopy for aspen forests in the Lake States. In addition, we will employ thermal imagery in conjunction with surface temperature data to estimate leaf temperatures that are critical to regulating metabolic rates. This effort will greatly enhance our ability to use anticipated HyspIRI data to concurrently map key variables associated with photosynthesis in forests.

Richard Vaughan/USGS
Simulated HyspIRI Data for Global Volcano Monitoring: Measuring Volcanic Thermal Features with a Wide Range of Temperatures

This proposed research is linked to three key science questions relating to monitoring global volcanic hazards identified in the HyspIRI Mission Study as related to the recommendations of the NRC decadal survey: 1) How can we help predict and mitigate volcanic hazards through detection of transient thermal phenomena? 2) How do volcanoes signal impending eruptions through changes in surface temperature and thermal flux? 3) How do variations in volcanic thermal features, such as the temperature and composition of crater lakes and hot spring pools, relate to volcanic processes? The first two questions can be studied by using data from both the visible-shortwave infrared (VSWIR) and thermal infrared (TIR) wavelength regions for volcanic features hotter than ~150 oC, and by using TIR data for cooler thermal features. The third question relates to cooler volcanic thermal features (<150 oC) that only emit measurable radiance in the TIR region. However, important information about the composition and acidity of crater lakes and hot spring pools based on visible color and spectral characteristics of the water and surrounding mineral deposits can be retrieved from hyperspectral VSWIR data.

Using examples of different types of volcanic thermal features with a wide range of temperatures (e.g., from lava lakes to crater lakes), this study will simulate HyspIRI data using existing MASTER, AVIRIS, ASTER and Hyperion data to model future HyspIRI measurements of these features, including visible color, spectral characteristics relating to composition, temperature, thermal flux, and sub-pixel thermal components. More specifically, this work will 1) study how future HyspIRI measurements of thermal features will compare to current remote sensing temperature and thermal flux measurements to continue time-series studies of volcanic thermal areas for monitoring applications, 2) study how HyspIRI VSWIR data will resolve visible color and spectral characteristics of volcanic crater lakes and hot springs, and 3) study how sub-pixel scale thermal features, of different temperatures, may be resolved by HyspIRI data with 60-m pixels and co-registered VSWIR and TIR data. Key questions regarding the use of such data for sub-pixel thermal feature analysis include: 1) How large does a hot sub-pixel feature, of a certain temperature, need to be for the data to resolve a thermally mixed pixel? 2) How large does a hot sub-pixel feature, of a certain temperature, need to be to saturate a pixel? 3) What assumptions and sources of error have the greatest effect on the results of sub-pixel thermal feature analysis? The answers to these questions are, in part, unique to each instrument and part of the proposed work will estimate these parameters for the HyspIRI instrument.

This proposed research is critical to defining the capabilities and role that HyspIRI and similar future satellite instruments will have in global volcano monitoring, because it will help determine the necessary requirements for instrument parameters - such as spatial and spectral resolution, temperature sensitivity, and radiometric resolution and accuracy - specifically for global volcano monitoring and studies.
